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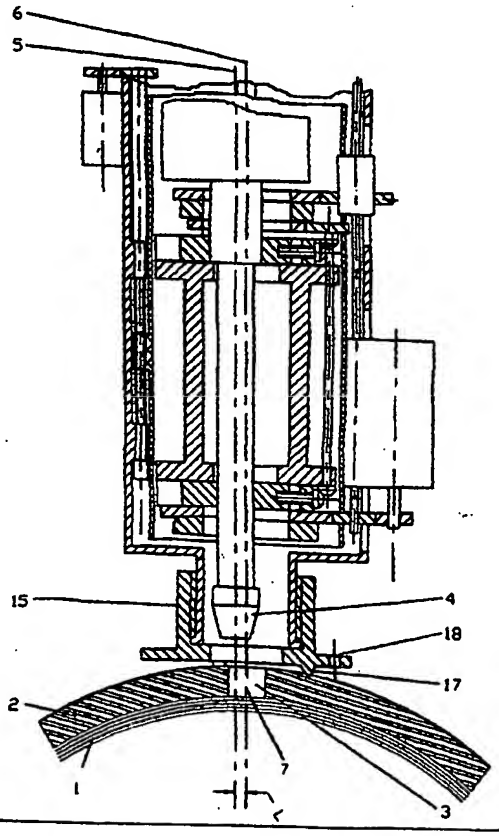
(54) Title: HAND TOOL FOR MAKING HOLES IN e.g. FIBRE-REINFORCED COMPOSITES, BY MEANS OF AN ORBITALLY MOVING CUTTER

(57) Abstract

The invention relates to a hand machine tool for the making of holes in an object (1) made of composite fibres, preferably with curved surface. The centre axis (7) of the hole (7) passes through a predetermined point on the surface of the object (1) and is oriented in a certain direction relative to the longitudinal direction of the fibres in a local surrounding of said point. The machine includes in combination a tool holder (4), rotating about its own axis (5) and a principal axis (6); a device (15, 18, 19) for adjusting the axis of rotation (5) of the tool holder (4) in the normal direction of the surface in said point; a device (32, 33a, 34, 35) for the axial feeding of the tool holder (4) relative to the object (1); a device (8, 9a, 21, 22, 23) for adjusting the distance (L) between the principal axis (6) and the axis of rotation (5) of the tool holder (4), and a device (15, 19, 20) for the taking up of forces and moments between the machine and the object (1) that originate from the making of holes, which forces rotate about the principal axis (6) and on one hand act in a direction that coincides with the axis of rotation (5) of the tool holder (4) and on the other hand act in a plane in the normal direction to said axis of rotation (5).



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HAND TOOL FOR MAKING HOLES IN E.G. FIBRE-REINFORCED COMPOSITES, BY MEANS OF AN ORBITALLY MOVING CUTTER.

The present invention relates to a hand tool machine for the making of holes in an object preferably made of composite fibre with a curved surface, whereby the centre line of the hole passes through a predetermined point on the surface of the object and is oriented in a certain direction relative to the longitudinal direction of the fibres in a local surrounding of said point.

Polymer composite materials have been familiar since the 1950s. These materials are composed of a protective and consolidating polymer, either thermoplastic or thermo-setting resin plastic, usually referred to as the matrix, and fibres (e.g. glass, carbon or aramide fibres), which may be regarded as reinforcing material. The fibres may be continuous and oriented in certain directions, or relatively short and arranged at random in the matrix. Composites with continuous and oriented fibres give products with superior mechanical characteristics to conventional polymer and metallic materials, in particular with regard to their weight-related strength and rigidity and have accordingly found widespread applications, for example in the aircraft and space industries. Composite materials for practical applications are often constructed from shells with double curvature, which have been joined to a stiffening sub-structure. A common method of joining is a bolted joint, in which the load is transmitted from one part of the structure to the other via shearing forces in the bolts. The strength of a bolted joint is influenced to a considerable degree by the quality and accuracy of the hole. Reference can be made here to three problem areas which can arise in conjunction with making holes in polymer

composite materials:

Low interlaminar strength. When machining laminated composite materials, the risk is present of the layers separating (delaminating) due to the low interlaminar strength. Extensive delamination damage can reduce the strength of the material.

Low heat-and-cold resistance of certain thermoplastics. The heat release during machining can cause the matrix to soften and to block the tool, making further machining impossible. In order to achieve good hole quality, therfore, effective cooling of the tool/hole edge is required, and the cut material (shavings, chips and grinding dust) must be removed continuously from the hole.

High resistance to wear of fibres. When composite fibres are machined by a process involving cutting, severe tool wear occurs as a consequence of the high wear-resistant characteristics of the fibre materials, which leads to high production costs.

Previously disclosed in two Swedish patent applications, 9201420-8 and 9203493-3, are two methods for forming a transcurrent hole in a fibre-reinforced composite material in such a way that the aforementioned problem areas are eliminated. A common feature of the two methods is that the opening is formed by causing a material-cutting tool on the one hand to rotate about its own axis and on the other hand to describe an orbital movement relative to the edge of the hole, in conjunction with which the fibre-reinforced material is positioned so that the axis of rotation of the

tool is essentially orthogonal to the longitudinal directions of the fibres at the edge of the hole.

Previously disclosed in the three U.S. patents 2 648 939, 3 119 210 and 3 533 195 and the three Swedish patents 99 369, 124 014 and 173 899 are machine tools with eccentrically rotating tools. These machine tools are all stationary, which means that they cannot be used when the object for the intended making of holes is so large that it cannot be moved to the machine or when it would bring about inacceptable costs to use these machine tools.

The object of the invention is to make available a machine in accordance with the introduction, which enables a high-quality making of holes in an object made of composite fibre. In accordance with the invention, this is made possible by the machine comprising the following in combination:

a tool holder rotating about its own axis and about a principal axis;
a device for adjusting the axis of rotation of the tool holder in the normal direction;
a device for axial feeding of the tool holder relative to the object;
a device for adjusting the distance between the principal axis and the axis of rotation of the tool holder;
and a device for taking up forces and moments between the machine and the object that originate from the making of holes, which forces rotate about the principal axis and on one hand act in a direction that coincides with the axis of rotation of the tool holder and on the other hand act in a

plane in the normal direction of to said axis of rotation.

Preferred embodiments of the machine in accordance with the invention are appearant from the dependent claims and from the accompanying description with reference to the drawings respectively. Fig. 1a shows a longitudinal section of a general drawing of the machine, whereas Fig. 1b shows a cross-section through the machine. Fig. 2 shows the machine during the making of holes in a composite material. Fig. 3 shows a longitudinal section of a general drawing of an alternative embodiment of a hand tool machine in accordance with the invention.

A laminate 1, shown in Fig. 2, consists of a number of laminae (layers) with continuous fibres, which laminae are arranged one on top of the other. The longitudinal directions of the fibres at a random point in the laminate define the tangential plane with the surface of the laminate. Positioned on the upper surface of the laminate is a hole template 2 in the form of a shaped plate with pre-drilled holes 3.

According to the invention, the machine comprises a tool holder 4, which is so arranged as to rotate on the one hand around its own axis 5 and on the other hand eccentrically about a principal axis 6. The first mentioned rotation is a achieved by the axis 5, in relation to the principal axis 6, being eccentrically mounted in two slides 8, which run in grooves 9a in the end walls of the rotor 10. The rotor 10 is driven by a low-speed motor 14 via a gear unit comprising the gear wheels 11, 12, and 13. The last-mentioned rotation is achieved by the tool holder 4 being

operatively connected to a motor 14b.

It can be noted that the eccentric rotation of the tool holder about the principal axis 6 takes place with a constant distance between the principal axis 6 and the axis of rotation 5 as will be explained in detail in the following. In the case of a known, numerically controlled movement, the corresponding movement takes place in linear increments, that is to say not as a rotational movement in the strict sense, which gives rise to a conflict between, on the one hand, the speed of machining and, on the other hand, the accuracy of machining. Furthermore, a numerical solution is associated with significantly higher costs.

According to the invention, the machine is executed with a device for adjusting manually the axis of rotation 5 of the tool holder in the normal direction to a tangential plane to the surface of the object. According to the illustrative embodiment (Fig. 2), this is made possible by means of said device for adjusting which, on one hand, comprises a sleeve 15 with three point contacts 17 on the surface of the hole template in an area around the point through which the centre axis 7 of the hole passes, which sleeve is fixed in a desired position and direction with a bolted joint 18, and on the other hand the outer casing 19 of the machine, which casing is arranged to slide into the sleeve 15, whereby the axis of rotation of the tool holder is arranged perpendiculary to the surface.

According to the invention, the machine also comprises a device for adjusting the distance L between the axis of rotation 5 of the tool holder 4 and the principal axis 6.

In the illustrative embodiment shown here, this is made possible by causing the axis of rotation of the tool holder to be mounted in the aforementioned two slides 8, which run in radial grooves in the end walls 9 of the rotor 10. The slides 8 are displaced with the help of slide screws 21, which in turn are activated, via an angle drive 22, by a shaft 23 (eccentrict shaft) mounted eccentrically in the end walls 9 of the rotor, the rotational speed of which shaft is adjustable. In this case the eccentric shaft 23 is able to rotate at the same speed as the rotor 10, but in the opposite direction (i.e. it remains stationary in relation to the rotor), when the regulating variable is stationary, under which conditions the position of the slides does not change. As the regulating variable changes, a corresponding change takes place in the speed of rotation of the eccentric shaft, in conjunction with which the slides 8 are displaced.

This is made possible through an arrangement containing a differential 24. The differential shaft 25 is connected to the motor 14a and is driven at a speed n_1. The differential shaft 26 is connected to a regulator. In this way the differential wheel 27 adopts the speed $n_1/2$ with the shaft 26 stationary. This rotation is transferred to the eccentric shaft 23 via the gear wheels 28, 29 and 30 and is geared at the same time to the same speed as the rotor. Through this arrangement, it is possible for the speed of rotation of the eccentric shaft in relation to the speed of rotation of the rotor to be regulated by the rotation of the shaft 26.

According to the invention the machine also comprises a

device for on the one hand a force rotating about the principal axis 6 and acting parallell to the axis of rotation 5 of the tool holder 4 and on the other hand a force rotating about the principal axis 6 and acting in the normal direction to the axis of rotation 5 of the tool holder 4. In the illustrative embodiment shown here, this is made possible by means of a bayonet socket 20, which locks the outer casing 19 of the machine in the sleeve 15.

Finally, according to the invention, the machine comprises a device for the axial feeding of the tool holder 4. In the illustrative embodiment shown here, this is made possible by executing the inside casing 31 of the machine with two slides 32, which run in grooves 33a in the outer casing 33 of the machine. Axial feeding of the tool holder 4 is obtained by causing the feed screw 34, which is connected to the motor 35, to rotate.

With reference to the illustrated embodiment in fig. 3, the tool holder 4 on the one hand rotates concentrically about the axis 5 under the influence of a motor 36, and on the other hand rotates eccentrically about the principal axis 6. The latter rotation is obtained through the motor 36 being eccentrically suspended from a rotatable spindle motor bracket 36, rotated by a motor 38.

The machine is executed with a device for manually adjusting the axis of rotation 5 of the tool holder 4 in the normal direction to a tangential plane to the surface of the object. In this embodiment, this is achieved by said adjustment device on one hand comprising a template 39, with a contact surface including an infite number of point

contacts on the surface of the object 1 in an area around the point through which the centre axis 7 of the hole passes, and on the other hand the lower part 33a of the outer casing 33 of the machine being provided with a sleeve 40, which is intended to be guided into a pre-drilled hole 39a in the template 39, whereby the axis of rotation of the tool holder is arranged in a desired position. In fig 3 the template 39 is not shown in direct contact with the surface of the object 1 for the sake of clarity.

The machine further comprises a device for adjusting the distance (L) between the axis of rotation 5 of the tool holder 4 and the principal axis 6. In the illustrative embodiment shown in fig. 3, this is achieved through the spindle motor bracket 37 consisting of a cylindrical, centered inner sleeve 42. The inner sleeve 42 is turnable in relation to the outer sleeve and the distance between the axis of rotation 5 of the tool holder 4 and the principal axis, which causes the distance between the axis of rotation 5 of the tool holder 4 and the principal axis 6 to be variable, owing to that the spindle motor is mounted in the inner sleeve and that the principal axis 6 coincides with the centre axis of the outer sleeve 41.

The machine has an arrangement for on one hand the taking up of a force rotating about the principal axis 6 and acting parallell to the axis of rotation 5 of the tool holder 4, and on the other hand the taking up of a force rotating about the principal axis 6 and acting in the normal direction to the axis of rotation 5 of the tool holder 4. In said embodiment the taking up of said forces is made possible in that the lower part of the outer casing

33 of the machine is arranged to be wedged between the template 39 and screws 43 that are mounted in the template 39. Said forces will then be taken up as contact forces (normal and frictional forces) between the lower part of the machine and the surroundings.

The axial feeding of the tool holder is made possible through the fact that the attachement means of the two motors are axially displaceable under influence of a hydraulic/pneumatic cylinder 44.

The invention should not be regarded as being restricted to the aforementioned advantages and illustrative embodiments shown in the drawing, but may be modified within the scope of the invention in many ways relating to, for example, the detailed design.

Patent Claims

1. Hand tool machine for the making of holes in an object (1) preferrably made of composite fibre with curved surface, whereby the centre axis of the hole passes through a predetermined point on the surface of the object (1) and is oriented in a certain determined direction relative to the longitudinal direction of the fibres in the local surrounding of said point, c h a r a c t e r i z e d by the following in combination:

a) a tool holder (4) rotating about a principal axis (6) and rotating about its own axis (5);

b) a device (15, 18, 19; 39, 39a, 40) for adjusting the axis of rotation (5) of the tool holder (4) in the normal direction to the surface in said point;

c) a device (32, 33a, 34, 35; 44) for the axial feeding of the tool holder (4) relative to the object (1);

d) a device (8, 9a, 21, 22, 23; 41, 42) for adjusting the distance (L) between the principal axis (6) and the axis of rotation (5) of the tool holder (4), and

e) a device (19, 20, 15; 33a, 39, 43) for the taking up of forces and moments between the machine and the object that originate from the making of holes, which forces rotate about the principal axis (6) and on one hand act in a direction that coincides with the axis of rotation (5) of the tool holder (4) and on the other hand act in a plane in the normal direction to said rotational

axis (5).

2. Hand tool machine in accordance with Patent Claim 1, c h a r a c t e r i z e d in that, said device for adjusting the axis of rotation (5) of the tool holder (4) in the normal direction to said point on the surface on the one hand a device (15; 39) with at least tree point contacts on the surface of the object (1) in the area around the point through which the centre axis (7) of the hole passes directly or indirectly, and on the other hand devices for adjusting the principal axis (6) in a normal direction to a surface, which includes said point contacts.

3. Hand tool machine in accordance with Patent Claim 2, c h a r a c t e r i z e d in that, the number of point contacts is three and that these are arranged essentially symmetrically around said point.

4. Hand tool machine in accordance with Patent Claim 2, c h a r a c t e r i z e d in that, said device comprises a template (39) including a surface with an infinite number of point contacts, i.e., the surface is arranged to be in a form fitted contact with an area on the surface of the object (1) around said point.

5. Hand tool machine in accordance with Patent Claims 2 and 3, c h a r a c t e r i z e d in that said device for adjusting the principal axis (6) comprises a sleeve (15) attached to said device, for which sleeve the direction of the centre axis coincides with said

normal direction and in which an element (19), that cooperates with the machine is arranged to be introduced and fixed.

6. Hand tool machine in accordance with Patent Claims 2 and 4, c h a r a c t e r i z e d in that said device (39, 40) for adjusting the axis of rotation (5) of the tool holder (4) in the normal direction to the surface of the object (1) in said point, includes a number of pre-drilled holes (39a) on the template (39), for which holes the centre axis coincides with said normal direction in said point and in which holes a sleeve is arranged to be introduced, which sleeve is formed on the lower part of the outer casing (33) of the machine.

7. Hand tool machine in accordance with Patent Claim 1, c h a r a c t e r i z e d in that, said device for adjusting the distance (L) between the principal axis (6) and the axis of rotation (5) of the tool holder (4) comprise two, relative to one another turnable sleeves (41, 42), of which the outer (41) is cylindrically centered relative to the principal axis (6) and the inner (42) is cylindrically eccentric and has a centre axis that coincides with the axis of rotation (5) of the tool holder (4).

8. Hand tool machine in accordance with Patent Claim 1, c h a r a c t e r i z e d in that, said device for adjusting the distance (L) between the principal axis (6) and the axis of rotation (5) of the tool holder (4) comprises at least a slide (8), mounted in an end

wall (9) of the rotor in the normal direction to the principal axis (6), which slide runs in a radial groove (9a) in said end wall (9) and carries the axis of rotation (5), whereby the slide (8) is displaceable in the normal direction to the principal axis (6) by means of at least one slide screw (21).

9. Hand tool machine in accordance with Patent Claim 1, c h a r a c t e r i z e d in that said device for axial feeding of the tool holder (4) relative to the object (1) comprises a feeding screw (34) operatively connecting the drive motor (35) and the tool holder (4).

10. Hand tool machine in accordance with Patent Claim 1, c h a r a c t e r i z e d in that said device for axial feeding of the tool holder (4) relative to the object (1) comprises a hydraulic/pneumatic actuatable cylinder/piston arrangement (44) which actuates drive motors provided between the outer casing (33) of the machine and which drive motors (36, 38) are axially displaceable in the outer casing (33) and operatively connected to the tool holder (4).

11. Hand tool machine in accordance with Patent Claim 1, c h a r a c t e r i z e d in that said device for the taking up of forces that originate from the making of holes, comprise elements that operate between the outer casing (19;33) and said device (15, 18, 19; 39, 39a, 40) for adjusting the axis of rotation (5) of the tool holder (4), which elements have a mutual operative connection based on form and/or friction

fit.

12. Hand tool machine in accordance with Patent Claim 11, c h a r a c t e r i z e d in that, said element includes a bayonet socket (20).

Fig 1a.

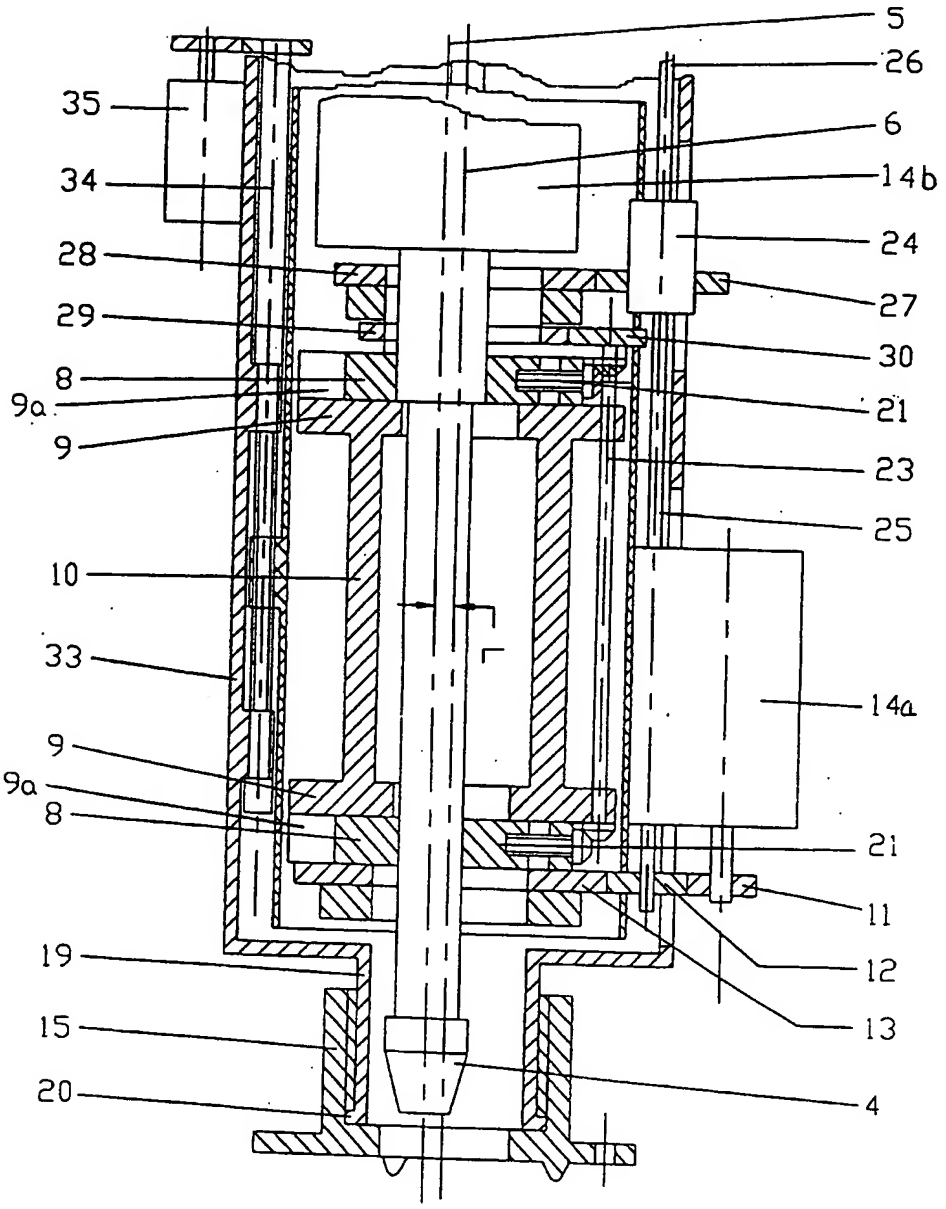
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Fig 1b.

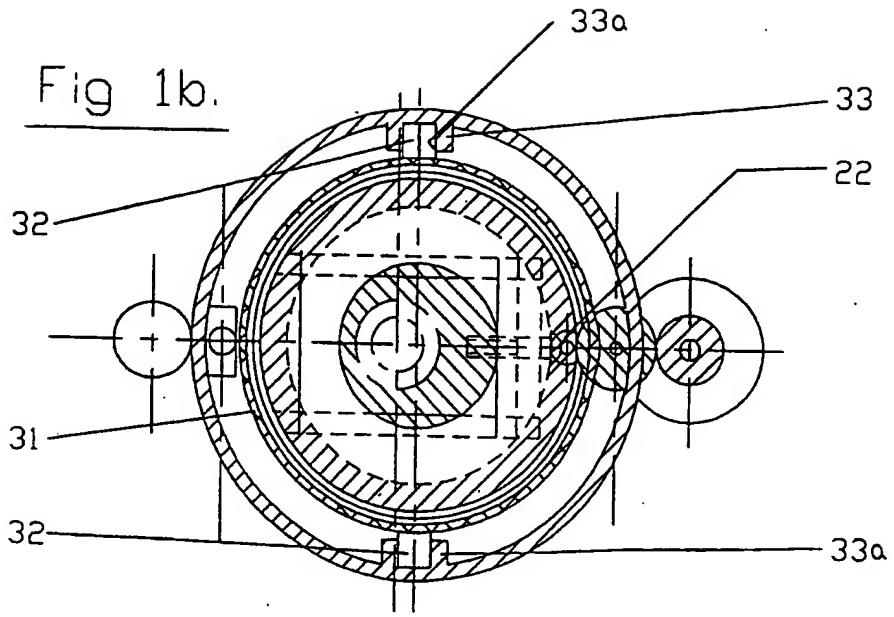


Fig 2.

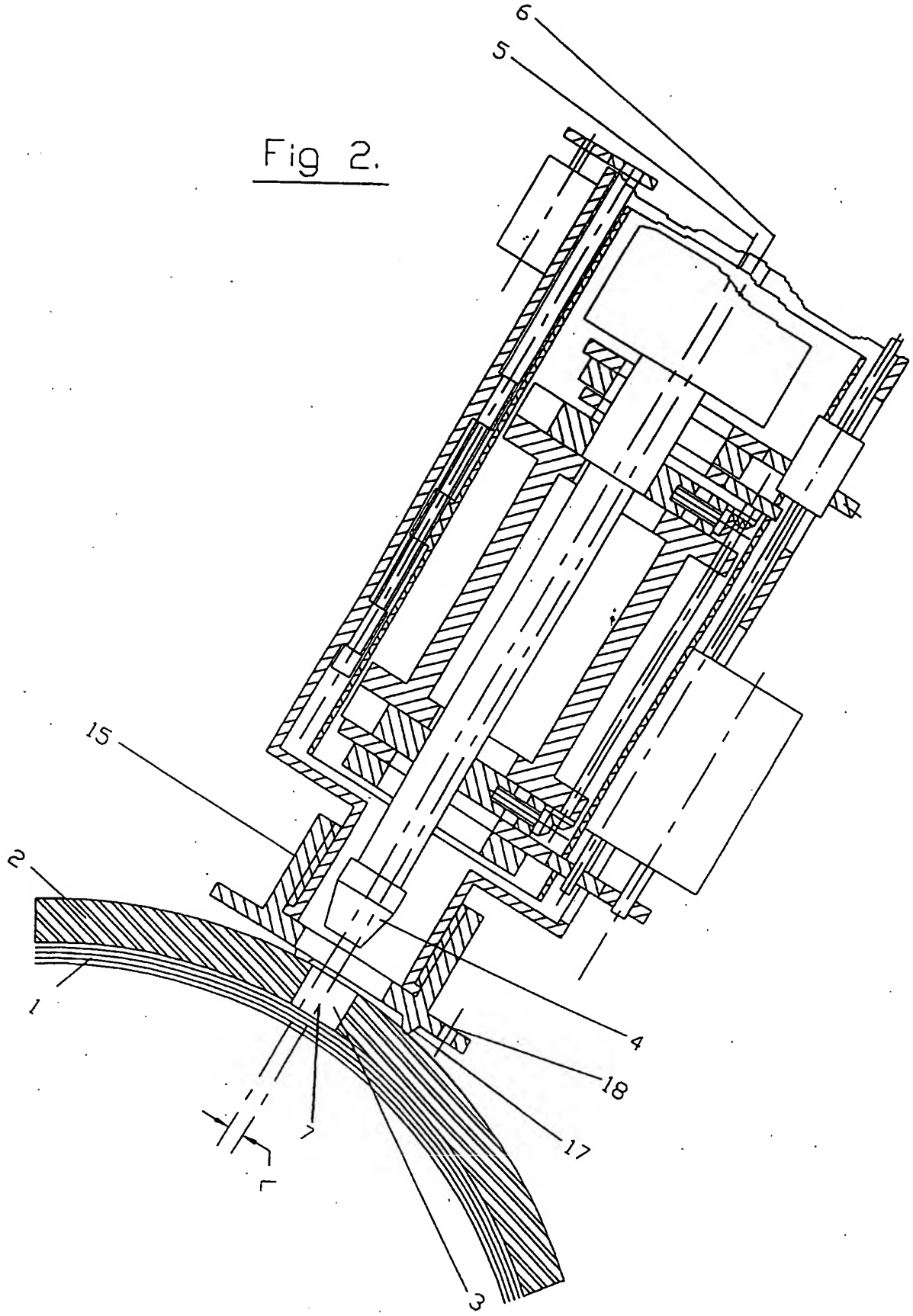
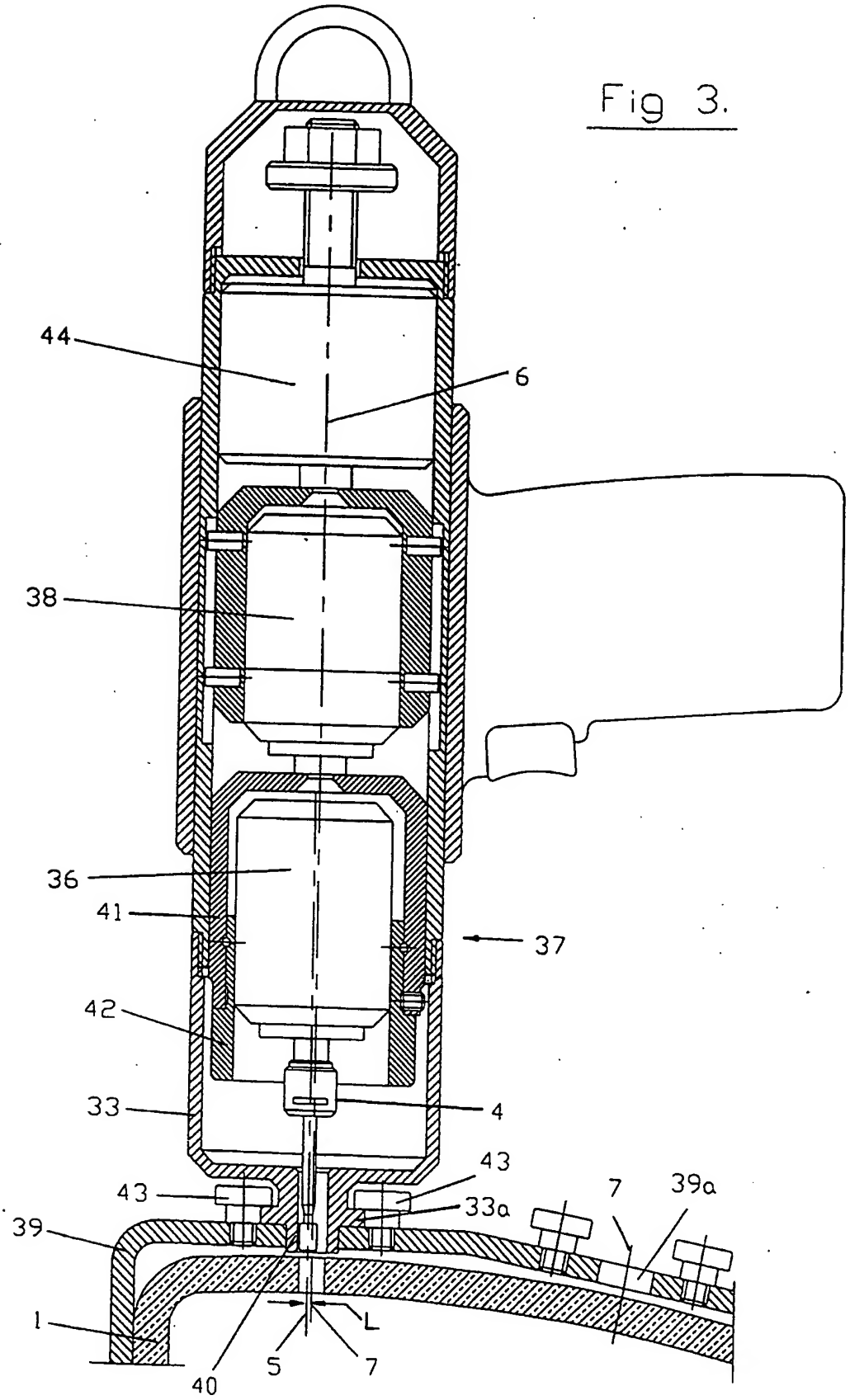


Fig 3.



INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 94/00085

A. CLASSIFICATION OF SUBJECT MATTER

IPC 5: B23B 35/00, B23C 3/12, B24B 5/00
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A		4,5,7-12
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A	SE, C, 173899 (H. DECKEL ET AL), 3 January 1961 (03.01.61), figures 1,2,6,7, claims 1,4	1-12
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[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 94/00085

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	SE, C, 99369 (AKTIEBOLAGET SEPARATOR), 9 July 1940 (09.07.40), figures 1-4, claim 1	1-12
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INTERNATIONAL SEARCH REPORT

Information on patent family members

16/04/94

International application No.
PCT/SE 94/00085

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SE-C- 173899	03/01/61	NONE	
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